River Restoration: Active vs. Passive Restoration Efforts, Alder Creek Example.

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February 1996
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Geography 501
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Abstract

The practice of river and stream restoration has increased with heightened environmental concerns and awareness. Many of these projects use structural modifications in an attempt to mimic natural landscapes. These structural modifications represent an active approach to river and stream restoration. Active restoration projects are well funded and extensively constructed. However, active efforts often fail due to poor design or as a result of adjacent poor land management practices. Passive restoration offers a less expensive, and often more successful alternative to river and stream restoration. The passive approach concentrates on eliminating damaging land management practices and allows the natural healing process to take place. Passive restoration efforts will likely provide more long-term benefits to rivers and streams than more expensive and sometimes detrimental active manipulation.

1. Introduction:

The utilization and exploitation of resources throughout the western United States has led to the degradation of countless ecosystems. Currently the United States has thousands of miles of polluted streams and 10,000 badly polluted lakes. Excluding Alaska, it is estimated the U.S. has lost 98% of it's wilderness area, 99% of it's prairie lands, and over 50% all wetlands (Berger 1995). Attempts to correct destructive actions of the past and to limit future negative impacts on natural landscapes are the foundation for many current environmental protective measures and vigilance against environmental degradation.

The ecological systems associated with water resources have been negatively impacted in the western United States through historic actions which focused on the development of a resource based economy. The finite nature of water resources within the West has changed the focus on water resources from one of development to corrections of negative impacts created by historic human actions. In an attempt to improve degraded ecological conditions, numerous stream and river related projects have been completed. These projects have been called corrections, rehabilitations, enhancements, improvements, and most recently restoration projects. In the majority of these projects an attempt has been made at "resetting the ecological clock" (Cairns 1991).

The purpose of this paper is to investigate the concept, approaches, and the associated successes or failures of river and stream restoration efforts.

The term itself, "restoration," is somewhat problematic. The question would follow, restore the river or stream to what? There was an evolution of terms associated with these types of projects. Originally called corrective, rehabilitations, enhancements, or improvements, the focus of river and stream projects started from environmental concerns often maintaining narrowly focused objectives. For example, the objectives have been to increase water quality or improve fish habitat while neglecting to address many accompanying components. The concept of "restoration" carries different implications. The process requires a holistic approach based on the ecosystem in its entirety. Recent legislative actions have mandated restoration efforts take place, increasing the need for a concrete definition of the term. In 1992, "restoration," as it applies to river, streams, and other aquatic ecosystems was defined by the National Resource Council as "returning an ecosystem to a close approximation of its condition prior to disturbance" (NRC 1995). The definition remains rather vague using the term "approximation." However, it is an improvement on past conflicts over what actually constituted a restoration project. "Approximation" was used because of severe difficulty achieving precise ecological restoration since many contributing ecological factors may have changed over time, or according to climatic conditions.

It is important to note that "stream improvements should not be used as a substitution for dealing with more complex causes of stream degradation such as grazing, logging, road construction and other impacts" (Gordon et al. 1992). This has been the case repeatedly in the past and continues today.

Success of a stream or river restoration project requires that design and planning follow a holistic or integrated approach. Still success appears to be far from guaranteed. Restoration methods often fail when efforts center on the manipulation of individual elements to obtain a certain objective while neglecting the larger inter-relationships present in the ecosystem. Failure to follow the holistic process has at times restored form while failing to achieve function, and vice-versa (Beschta/Platts 1986).

Numerous river restoration projects have taken place throughout the West although the actual number is hard to obtain as a result of the numerous agencies involved, the loosely defined nature of the term "restoration," and conflicting opinions regarding many project's actual objective. Several agencies and municipalities have conducted restoration projects, including: the United States Forest Service, the Bureau of Land Management, the Bonneville Power Administration, the National Parks Service, and the Los Angeles Department of Water and Power, with varying degrees of project success. The Sikes Act PL 93-452 and the Knutson-Vandenberg Act (Forest Management Act of 1976) assign funds specifically to restoring streams on National Forest lands (Reeves/Roelofs 1982). Under the Siskiyou National Forest Management plan $1,700,000 is to be spent restoring rivers over a three year period. The Bonneville Power Administration spends more than $5,000,000 annually to install instream structures as part of their river restoration program (Frissel/Nawa 1992). While the number of actual river restoration efforts remains elusive there has been a dramatic increase in the number of projects from the mid 1980's to the present, a trend that in all likelihood will continue (Canaday 1996).

Two distinct approaches have evolved in river restoration, an active or structural intervention and a passive approach. The division between these two philosophies has become more extreme as the practice of river restoration expands. Each approach contains certain positive and negative aspects associated with its implementation.

2. Historical Background:

When the United States was in its "Young Republic" stage from 1781-1870 there was a perception that the resources in the West were inexhaustible (Jackson 1995). Following this perception the federal government sought to transfer land stewardship to states and private land holders for the exploitation of natural resources. The federal government established several land disposal acts to promote western exploitation of resources including: the Homestead Act - 1861, the Mining Act - 1866, the Desert Land Act - 1877, the Timber and Stone Act - 1892, and the Stock Raising Land Act - 1919.

A "period of awakening" followed beginning in 1870 with the realization that natural resources were indeed exhaustible. This realization lead to an era of conservation and eventually to today's environmental movement which began in earnest in the early 1960's (Jackson 1995).

3. New Focus:

Since realizing the finite nature of natural resources, new policies and legislation are often geared towards the protection and restoration of remaining resources. The focus has changed so dramatically that Dr. Berger, a consultant for the National Research Council, stated:

> "Statutory and policy authorizations for the conduct of environmental restoration by the federal government are so widespread throughout the framework of the nation's federal natural resource and environmental law that a sound legal foundation exists for the conduct of major environmental restoration programs affecting virtually every basic type of natural resource in the nation" ((a.)Berger 1991).

Many of these statutory and policy authorizations refer to aquatic natural resources, specifically rivers and streams. A partial list of aquatic related authorizations includes: the Wild and Scenic River Act of 1968, the National Environmental Policy Act of 1970, the National Forest Management Practices Act of 1976, the Surface Mine Reclamation Act 1977, and the Water Resources Research Act of 1984 ((a.)Berger 1991). Portions of all these Acts relate to protecting or restoring rivers and streams.

4. Restoration Approaches:

The debate between advocates of the two approaches to river and stream restoration, the active and passive approach, has grown as the practice of restoration increases. The goals remain consistent while the methods of accomplishing these goals are philosophically opposed. From a holistic stand point the common goals include restoring water quality, hydrologic balance, riparian vegetation, mechanisms of colonization / habitat for macroinvertibrates, and fish habitat (Gore 1985). The active approach attempts to dictate the river/stream dynamics, while the passive approach lets the river/stream establish the dynamics and simply works to aid the natural processes that are deemed beneficial.

Active Approach-

Active restoration efforts have been used on a limited scale to improve fisheries habitat for over a century (Beschta et al. 1995). The first large scale attempts to manufacture instream structures occurred in the midwestern United States during the 1930's, utilizing the labor surpluses of the Civilian Conservation Corps (Hall/Baker 1982). The most widely applied approach to river and stream restoration entails an active intervention which dictates the re-development of a specific aquatic ecosystem. The active approach depends heavily on the construction and / or placement of structural stream features, including: pools, point bars, reinforced banks, boulder placement, erosion control devices, and spawning gravels, in an attempt to create a stable stream channel (Gordon et al. 1992). Supporters of the active restoration approach refer to river restoration projects as "the process of recovery enhancement" (Gore 1985). Volumes of literature have been produced regarding active restoration, creating cookbook type environment for restoration projects. In 1992 the United States Forest service published the Stream Habitat Improvement Handbook (Seehorn 1992), the latest edition of a publication that began in 1952. The book provides a step by step, "how to" manual for actively repairing degraded streams.

Proponents of the active approach realize the dynamic nature of a stream channel but feel design plans that recognize the geologic, hydrologic, hydraulic, and geometric factors present in a stream will lead to the construction of a successful and stable channel (Hasfurther 1985). Generic formulas have been calculated to determine where stream modification should take place in active restorations, resulting in some basic "rules of thumb."

Introduced meanders should be placed between five to seven stream-widths apart, which equals one half the meander wave length (Hasfurther 1985). If historic air photos exist they can be used to estimate stream widths prior to disturbance. Similar to meanders, pool/riffle formations should be constructed every five to seven stream widths. When placed on third, fourth, or fifth order streams the riffle slope should maintain a slope of 2.3 percent (Gordon et al. 1992).

To achieve bank protection and promote stability the active approach depends on numerous man-made structural components. The recommended bank is sloped at a one to two ratio. Structural fortifications include lining banks with riprap, fencing, nylon, steel, tires, concrete slabs, plastic sheeting, and vegetation. To decrease water velocities and direct flow weirs, groynes, revetments, gabions, and strategic boulder placement are used. As a "rule of thumb" diverting or protective structures provide protection to adjacent banks three to five times the length of the structure itself (Gordon et al. 1992). Flow deflectors should be less than one half the stream-width, less than half a meter in height, or .15 to .3 meters above the low flow elevation (Gordon et al. 1992).

Woody debris enhancements can be accomplished by introducing downed trees. The down trees should be anchored to the stream bank with the trunk portion facing up stream. Anchoring should be done with wire or cable in a position which will resist scouring. Eventually a sediment and vegetation anchor should form (Gordon et al. 1992).

The cookbook approach to active river restoration has developed to the point that a simple set of tables can be used to prescribe actions and anticipate results (See Appendix A).

Passive Approach-

Proponents of the passive restoration approach believe "a dollar in stewardship is worth $10,000 in structures" (Platts/Nelson 1985). An increasing number of studies support the passive philosophy. The passive approach requires better land management within watersheds, specifically in areas adjacent to stream-side vegetation. Once new land management has eliminated or corrected the activities causing negative impacts the natural healing process can take place. In many cases the natural processes may be aided through the planting or reintroduction of native flora. To illustrate the philosophy behind passive restoration the following question can be asked;

> "If most streams are currently in a degraded state due to historical management practices that have heavily impacted riparian vegetation, doesn't it seem likely that a change in management and improvement in vegetation may represent an important solution?" (Elmore/Beschta 1988).

Instead of introducing man-made structural components such as riprap, weirs, gabions, and geotextile fabrics to a degraded stream in an attempt to dictate stream dynamics, we should let the "stream tell us" how it's going to develop and offer aid where appropriate. This is the foundation of the passive restoration approach (Elmore/Beschta 1988). Modifying stream channels through expensive structure construction has been shown to seldom provide long term solutions in degraded systems.

A study by Platts and Nelson showed that if a stream is provided a rest from grazing, significant improvements in riparian vegetation, stream bank stability and overall channel conditions are likely to follow without active intervention (Platts/Nelson 1985). The study was conducted on Big Creek in Utah. Historically the stream had been heavily grazed and extremely degraded by livestock. A fence was constructed eliminating livestock access along 600' of Big Creek. The neighboring sections remained open to cattle access, functioning as the control for the project. A total of 183 transects were established throughout the study area to monitor changes in stream conditions. In addition, numerous structural modifications or "enhancements" were made. The results, tracked over eleven years, 1970-1981, showed degraded streams protected from grazing have the ability to restore themselves to a great extent. Riparian vegetation, habitat, channel bank, and streambed stability all improved. The improvements in riparian vegetation were more dramatic and rapid than structural improvements. The introduced structures did improve the pool to riffle ratio but also trapped large amounts of fine sediments, counteracting other natural habitat improvement from occurring (Platts/Nelson 1985).

A similar study involving the recovery of willows and sycamores within a riparian corridor following the exclusion of livestock supports the implementation of passive stream restoration. In 1983 a portion of open grazing land was acquired by Henery W. Coe State Park in central California. Along the North Fork Pacheco Creek, an intermittent stream, the riparian corridor contained plots of mature sycamores, one young sycamore and five willows. By 1985, following a two year reprieve from grazing, the same corridor contained over 320 willows, 16 sycamores and one cottonwood. The overall riparian corridor and rates of individual growth were dramatic. The improved riparian vegetation added to stream bank stability and increased habitat (Smith 1988).

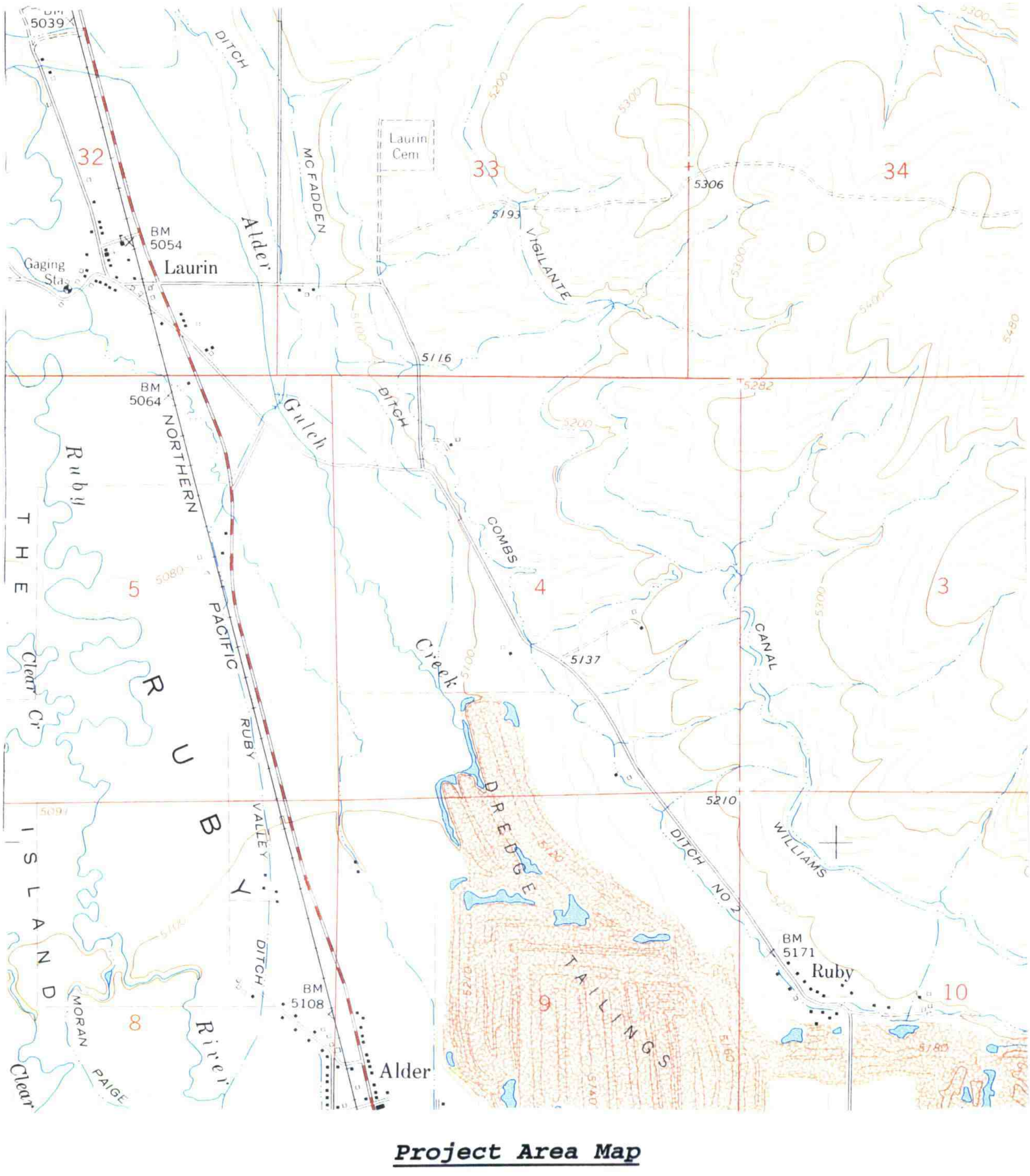
A further example of success through passive practices was illustrated in a study on ten streams in Oregon which went from intermittent flow to perennial streams through management changes which allowed riparian vegetation to flourish (Stuebner 1988). There remain many physical and social challenges to fencing riparian corridors, especially on private land, but once these obstacles are over come the resiliency of native flora produces observable improvements within months (Reichard 1988).

Justification to use a passive approach over active intervention can also be found in the failure rates associated with artificial habitat structures. A study published in 1992 studied the failure rates of 161 artificial instream structures constructed in rivers throughout western Oregon and Washington. The study found that a flood smaller than a ten year event causes structural or functional failures rates of greater than 50%. The probability that a ten year flood event occurs in the first decade following installation of a structure is 65%, increasing to 88% in the first twenty years. Active structural restoration is expensive and the prospects of producing long-term benefits have been shown to be slight (Frissel/Nawa 1992).

The use of active and passive river/stream restoration measures have been combined in some projects. The intent of this process is to speed the natural healing process while implementing land management changes. In projects that have utilized both approaches it is often difficult to attribute environmental improvements to a specific approach. This is the case with the Alder Creek restoration project.

The Alder Creek Restoration Project

1993-1995



Project Area Map

All statistical data on Alder Creek came from office documents and personal interview at Urbani and Associates, Bozeman, Mt., 1995, (unless noted otherwise.)

5. Introduction:

Alder Creek provides a good example of an active stream restoration project that was aided by passive restoration efforts. Located in the western United States, Alder Creek is typical of many small scale restoration projects constructed today. In addition to active manipulation of instream structures and dynamics, several aspects of passive restoration have also taken place. The result of these efforts is a stream that currently supports a substantial fishery and a healthy riparian corridor.

Similarities with other active restoration projects can be found in the Alder Creek Project. The objective of the Alder Creek restoration was focused on creating a sustainable Brown Trout (Salmo Trutta Linnaeus) and Rainbow Trout (Salmo Gairdneri) fishery. In pursuing this objective several other aspects of the ecosystem were enhanced to produce improvements in fish habitat.

The Alder Creek restoration project, like many other restoration efforts, is plagued by the lack of baseline data from which to evaluate the ultimate success or failure of restoration efforts. Unfortunately the lack of baseline data and failure to establish post project monitoring programs limit the development of valuable information which could be used to improve restoration efforts.

6. Setting / Background:

Alder Creek is located in the Ruby Valley of southwestern Montana's Madison County. The headwaters, Prospect Creek, come out of an area which was subject to extensive gold exploration beginning in the 1840's, known as the Golden Gulch (Pace 1991). Active commercial mining continued through 1945 with as many as 35,000 people residing in the small canyon during the height of the boom in 1865 (Pace 1991). Massive floating dredges were utilized on Alder Creek. At one time five dredges worked Alder Creek, each one excavating over 2000 cubic yards of material per day. The dredges were placed in man-made impoundments in the creek, depositing miles of extensive mining tailings directly into the streambed. Dredging operations were stopped in 1922 (Gilman 1995). To date, over 200 million dollars in gold has been extracted from the Alder Creek drainage (Pace 1991). As a result of the tailings placement the flow of Alder Creek actually disappears into the tailings for extended lengths. The result of the mining activity is a stream which has periodically been subject to tremendous sediment flows which have decimated the downstream ecosystem (Appendix B, Figure 1).

Further down the drainage the Ruby Valley has historically been utilized for agricultural production and livestock grazing. The results of the agricultural and ranching activities have been a degraded ecosystem along and including Alder Creek. Along many sections of Alder Creek the stream and its neighboring lands were used for livestock pasture and watering areas. Livestock access was unrestricted along the project section of the stream. Native vegetation was largely removed to enhance and expand pasturelands for livestock grazing.

The restored section of Alder Creek contains approximately 1000 linear feet, maintains a slope of 1.5 percent, and lies just upstream of the confluence with the Ruby River. Restoration cost were between $10,000-$12,000, which is in line with average industry cost estimated at $37/meter (Cairns 1995).

Over the last fifty years the high flow of Alder Creek through the project section was calculated to be approximately 170 cfs (Gilman 1995). Typically summer low flows have been estimated at ten cfs (Cambell 1995). In many respects the upstream mine tailings cause Alder Creek to have a flow regime similar to that of a spring feed stream, producing less extreme fluctuations during seasonal changes. Periodic increases in summer flows are attributed to increased irrigation through return flows and mixing irrigation ditch flows.

7. Project Goals and Objectives:

The ranch encompassing the lower stretch of Alder Creek was sold in the early 1990's. The new owners sought to restore the aquatic ecosystems along Alder Creek and the neighboring Ruby River. The primary goal of the Alder Creek restoration project was to improve fish habitat and restore spawning / rearing areas.

Prior to almost any stream or river related construction a variety of permits must be obtained from both the state and federal agencies with jurisdiction in water related development. Accordingly, several permits were obtained to undertake the Alder Creek restoration project. The state of Montana required a 310 Natural Streambed and Land Preservation Act Permit, a 124 Montana Stream Protection Act Permit, and a 3A Short Term Exemption from Surface Water Quality Permit which restricted construction before March 15, 1993 and after November 30, 1993. At the federal level the Army Corps of Engineers required a 404 permit. In addition, the involved section of Alder Creek lies within the Ruby Valley Conservation District which was advised of anticipated project activities. The permits allowed the use of a track excavator to construct 1000 feet of instream habitat enhancements, including: streambed manipulations, construction of spawning, rearing and holding areas, placement of excavated materials as point bars, fixing sediment producing banks, and replacing a flow restricting ranch bridge. The construction objective stated on permit applications was to enhance fish habitat within Alder Creek. Statements of this type normally make permits easily obtainable.

8. Methods:

Both active and passive restoration efforts were applied in Alder Creek. A greater emphasis was placed upon active restoration through the construction of instream structures, bank stabilization and introduction of flora and fauna. In addition, natural aspects of the stream ecology deemed undesirable were removed in favor of man-made structures. Passive restoration efforts included the elimination of livestock grazing and curtailing upstream mining activities. The halt of upstream mining was outside the control of those conducting restoration efforts.

Active Restoration

To restore Alder Creek an emphasis was placed on active measures which were intended to correct fish habitat insufficiencies and speed the establishment of a sustainable fishery. As a result of upstream mining the streambed had been filled with fine sediments washed from the tailings. In addition, livestock grazing had caused degradation resulting in a stream which was excessively wide and shallow causing increased stream temperatures. This is a documented characteristic of livestock's impact on stream channels (Smith 1988).

Of primary importance in this restoration effort was the construction of an upstream sediment trap to protect the restored section of stream from further fine sediment deposits. Prior to restoration, fine sediments were deposited in layers up to 3 feet deep. These sediments were excavated as part of the active restoration effort. In addition, three beaver dams behind which the deepest sediment layers had formed were blown up and the beavers trapped and removed.

The constructed sediment trap is approximately 60 feet long, 9 feet wide, 8 feet deep, and located directly upstream of the restored stream segment. During low flows, water backed up by a granite boulder weir at the down stream edge of the sediment trap will deposit suspended sediments into the pool as flow velocities deminish. All boulders used in restoration are of adequate size to maintain placement in 25 year flood event. During high flows it is anticipated that sediments will stay suspended throughout the restored stream segment (Appendix B, Figure 2).

Following the sediment trap a series of angled boulder weirs were constructed, producing a cascading effect and increasing the dissolved oxygen content through the project stretch (Appendix B, Figure 3).

Within the next 1000 linear feet a series of eight rearing, holding, and feeding pools were constructed, three in the top 165 feet of the channel, five in the bottom 400 feet. Two of these pools were enhancements of already existing geomorphic features. The remaining six pools excavated to depths ranging from 2 feet to 6 feet (Appendix C, Figures 1&2).

Associated with each pool a series of point bars were constructed with excavated sediment material along the inside bank where lower water velocities are present. Point bars were re-vegetated with pasture grass seed. Pasture seed mix was chosen over attempts to re-seed native flora since native species had long ago been replaced with pasture vegetation. The outside banks, referred to as hard banks, were reinforced with riprap along slope toes, woven geotextile fabric and vegetative cover. Riprap specifications require rock to be crack free, angular, have a bulk specific gravity not less than 2.5, absorption not more than 2 percent, and have a diameter of approximately 16 inches. Immediately upstream of the pools, gravel/cobble was placed in the channel. The gravel/cobble is kept from scouring down stream by boulder weirs which angled down stream towards the point bars. In addition to stabilizing gravel/cobble placement, the weirs direct water flow towards the hard bank and deeper areas of the pool, protecting the softer point bars. On the down stream edge of the pools spawning gravels have been installed creating a ripple to oxygenate spawned fish eggs (Appendix C, Figure 3).

Passive Restoration

The active emphasis of the Alder Creek restoration project was undoubtedly aided by the passive restoration elements which also took place. The new owners had neither the desire nor the financial need to ranch cattle on a profitable scale, which often creates negative impacts on aquatic ecosystems (Woodson 1995). Prior to the new ownership 500 head of livestock were grazed in and around Alder Creek (Gilman 1995). In one location Alder Creek actually ran through a livestock holding area functioning as the watering site for penned livestock. Today livestock are totally restricted from the restored section of Alder Creek.

The removal of cattle has led to natural bank stabilization. In two years natural vegetative cover has grown quickly with the elimination of grazing pressure.

While outside the control of the participants in the Alder Creek restoration process, the fact that mining in the upstream drainage has stopped has had perhaps the most profound impact on natural restoration. The tailing piles still occupy the stream channel upstream but have become increasingly more stable over time. Turbidity associated with active mining is no longer a threat to the Alder Creek aquatic ecosystem. Seasonal variation in stream flows still produces increased sediment levels; however, the sediment levels do not appear to be drastically different than those which occur naturally. At times livestock activity upstream have increased sediment loads. These increases are now less problematic with the installation of the sediment trap.

9. Post Project Analysis:

Conducting a post project analysis on the Alder Creek restoration project is a difficult task. There was no baseline data collected prior to construction, eliminating the possibility of conducting a quantitative comparison between before and after conditions. A series of before and after photographs is the only form of documentation available for comparison (Appendix D). Quantitative assessments of water temperature, dissolved oxygen content, suspended sediments, and fish populations are needed to produce a more valuable post project analysis. In order to produce a reliable evaluation of stream restoration projects, post project monitoring should be conducted over a span of ten years, making comparisons to the original baseline data (Kondolf/Micheli 1995).

Visually the restored section of Alder Creek appears to be functioning well. Both Brown and Rainbow trout reside in the 1000 feet of restored stream. The extent to which the fish populations have increased, or possibly decreased, is not known. Vegetation fills the riparian corridor providing habitat, cover, and increased bank stability. It is probable that a passive effort, the removal of livestock, had more to do with increased vegetation than active measures.

Structurally the modifications made to the stream channel have thus far resisted displacement and appear to be functioning well. The boulder weirs, point bars, and pools remain intact, performing their designed functions. The sediment trap, which was originally excavated to a depth of 8 feet, is now 5 feet deep. In two years significant sediment accumulation has occurred. The cause of the significant sediment deposit is continued livestock access to Alder Creek at points upstream. In the future a re-excavation of the sediment trap will be required, which was anticipated prior to construction.

A possible future problem for Alder Creek is the proposed re-working of upstream mine tailings. The Hanover Gold Corporation has obtained a exploratory license from the Montana Department of Lands to explore mining potential in old tailings. If deemed profitable the mine would operate under the Small Miners Exclusion Statement until the 36,500 tons/year threshold is reached. Additional mining has been proposed further upstream in Prospect Gulch. An application was submitted in 1993 by the M&W Milling and Refining Inc. to construct a mill capable of processing 100 tons/ore/day. The facility would include a three acre gravity impoundment and quarter acre cyanide impoundment. These mining activities would adversely effect the restored section of Alder Creek. Sediment levels would be too great for the sediment trap to protect the restored section of creek.

10. Conclusion:

Instead of spending millions of dollars annually on non-effective artificial stream restoration, the emphasis should be on better land management and passive restoration. Studies continue to show the need to consider physical and biological processes in a regional or watershed context when considering aquatic ecosystems.

In order for the science of river/stream restoration to improve "agency professionals must be able to evaluate restoration efforts accurately and more comprehensively," ignoring project bias and predetermined agenda's ((b.) Berger 1991).

The desire to see immediate results, combined with a need to feel something is actively being done, has led river/stream restoration down the sometimes counter-productive path of active restoration. In addition, the presence of funding sources perpetuates many ill conceived active projects. Restoration efforts should heed the recommendation of the National Resource Council to implement better land management practices and allow natural restoration to occur. Specifically the National Resource Council calls for: accelerating erosion control programs, revising grazing policies, pursuing active measures only when passive measures have been proven inadequate, and removing dysfunctional, artificial structures to re-establish natural hydrologic conditions (NRC 1992).

Heeding the National Resource Council's recommendation of moving to an emphasis of passive measures, followed by comprehensive monitoring plans, increases the potential for positive results in river/stream restoration. The approach enables scientific advancement and saves money. Admittedly, results take longer to achieve, but long-term success is the ultimate goal, not overnight visual alternations.

Appendix A

Table 1. Recommended Widths of Riparian Buffer Strips Necessary to Protect Water Quality and Aquatic Life in Streams

Function of buffer strip	*Recommended Width*
Protect H2O quality from logging	8m+0.6m per 1% of slope
Protect H2O quality from logging in municipal watersheds	16m+1.2m per 1% of slope
Protect aquatic life from logging	minimum of 30
Protect H2O and fish	25m + additional width to support riparian vegetation
Protect streams from adverse land management practices	30m
Protect aquatic environment	minimum of 15m

Modified from Brinson, M.M.., Riparian Ecosystems, Their Ecology and Status, Series: FWS10BS;-81/17, National WaterResearch Analysis Group, U.S. Fish and Wildlife Service, Washington, D.C., 1981.

Table 2. Advantages and Disadvantages of Riprap Commonly Used Bank Protection Techniques

Benefits -

1. Provides substrates for benthos and periphyton
2. Provides cover and reduces current velocities
3. Provides for stable channel bottom for colonization
4. Provides a source of gravel substrate material for fish spawing beds
5. Reduces erosion, secondarily protecting instream habitat for sediment fouling

Disadvantages -

1. Does not provide riparian habitat for wildlife and can eliminate existing habitat
2. Too much riprap results in loss of riparian habitat diversity and availability
3. May not be compatible with adjacent land use practices (especially agriculture and forestry)

Modified from Cairns, John Jr., "Rehabilitating Damaged Ecosystems," 1995.

Table 3. Instream Habitat Structure to Enhance Establishment of Fish Assemblages

Structure	Utility	Siting Criteria
Deflectors	Redirecting current	Streams of various size
	Stabilizing thalweg	Gradients <3%
	Scouring pools	Bank stability opposite deflector
	Silt removal	Alternating banks, 5-7 channel
	Erosion abatement	widths of senicous flow
	Consolidating low flows	Anchor into bank 1.5m
	Increased pool/riffle ratios	Efficient with natural materials
Dams	Pool formation/control	Low end of steep break in gradient
	Holding spawning gravels	Stable substrate and banks
	in upstream areas	Anchor into bank 2m
	Fish passage	Successive structures, 5-7 channel widths
	Sediment control	Heights<0.3m
	Collection of organic material	Spawing gravels between passage
Boulder Placement	Added rearing habitat	During low flow
	Cover	0.6-1.5m diameter
	Restore meanders	Granitic type preferred
		Embedded a short distance
		Greatest effect in reaches with <20% pool area
		Natural material are most economical
Trash Catchers	See dams (above)	Small, headwater streams
		High gradient
		1/3 cost of log dams

Modified from Wesche, T.A., in "The Restoration of Rivers and Streams," by Gore, J.A.. Butterworth Publishing, Boston, 1985.

Table 4. Levels of Disturbance in Streams and Rivers, Location of Source of Colonizers, and Observed Rates of Recovery

Condition	Source	Recovery pattern	Time
Entirely destroyed	none	Primary succession	5-25 yrs
Entirely destroyed	Hyporheic	Primary/secondary succession	1-5 yrs
Reach destroyed	Upstream/downstream	Primary succession	90-400 days
Reach destroyed	Upstream/downstream; hyportheic	Secondary succession	40-250 days
Species abundance reduced in reach	Upstream/downstream; hyportheic	Secondary succession	25-100 days
Species abundance reduced in patches	Upstream/downstream hyportheic	Secondary succession	10-75 days

Modified from Gore, J.A. and Milner, A.M., Environmental Management, Volume 17, 1990.

<u>***Appendix B, Figure 1***</u>

Mining impacts along Alder Creek (1995)

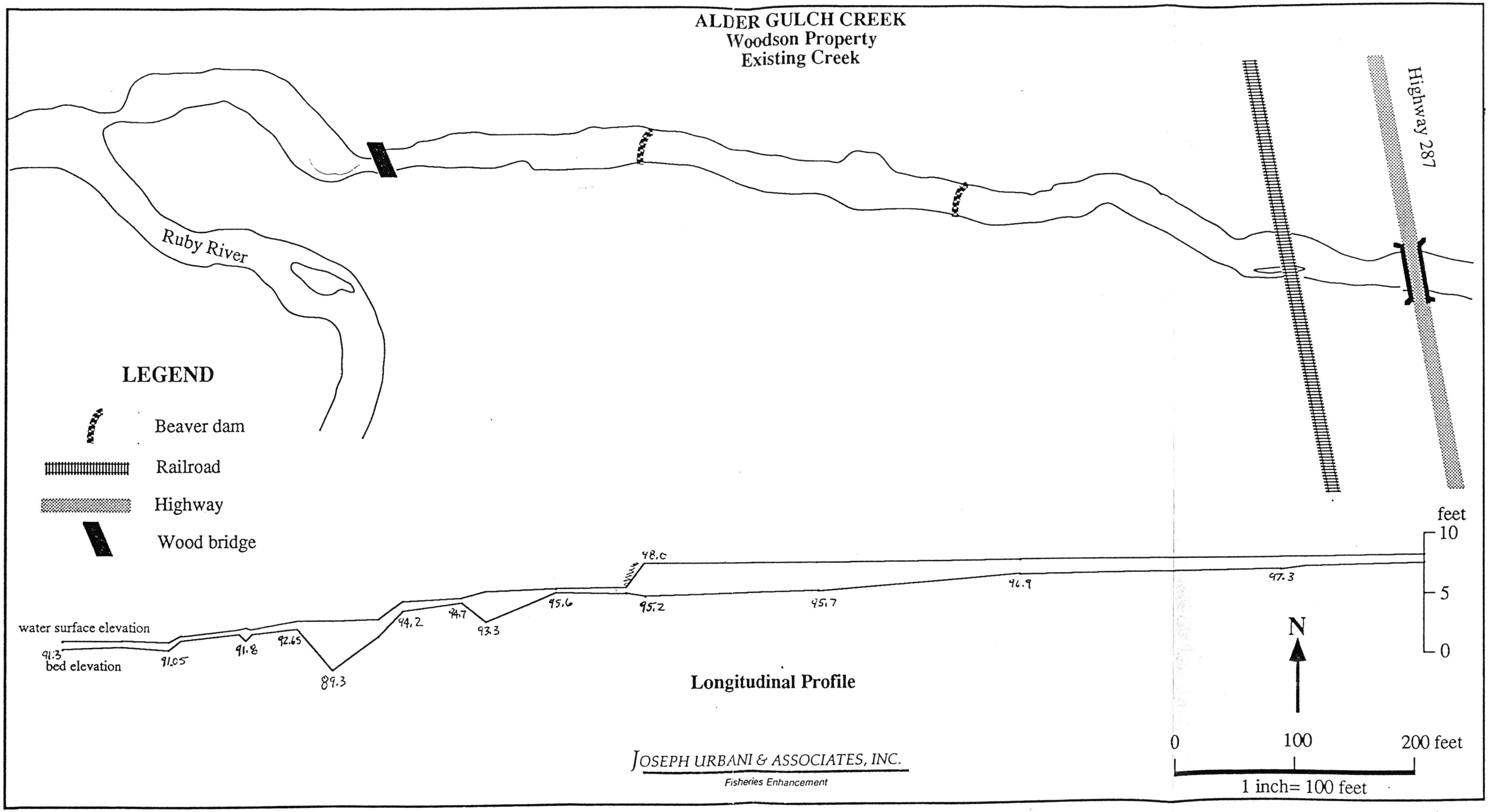
Appendix B, Figure 2

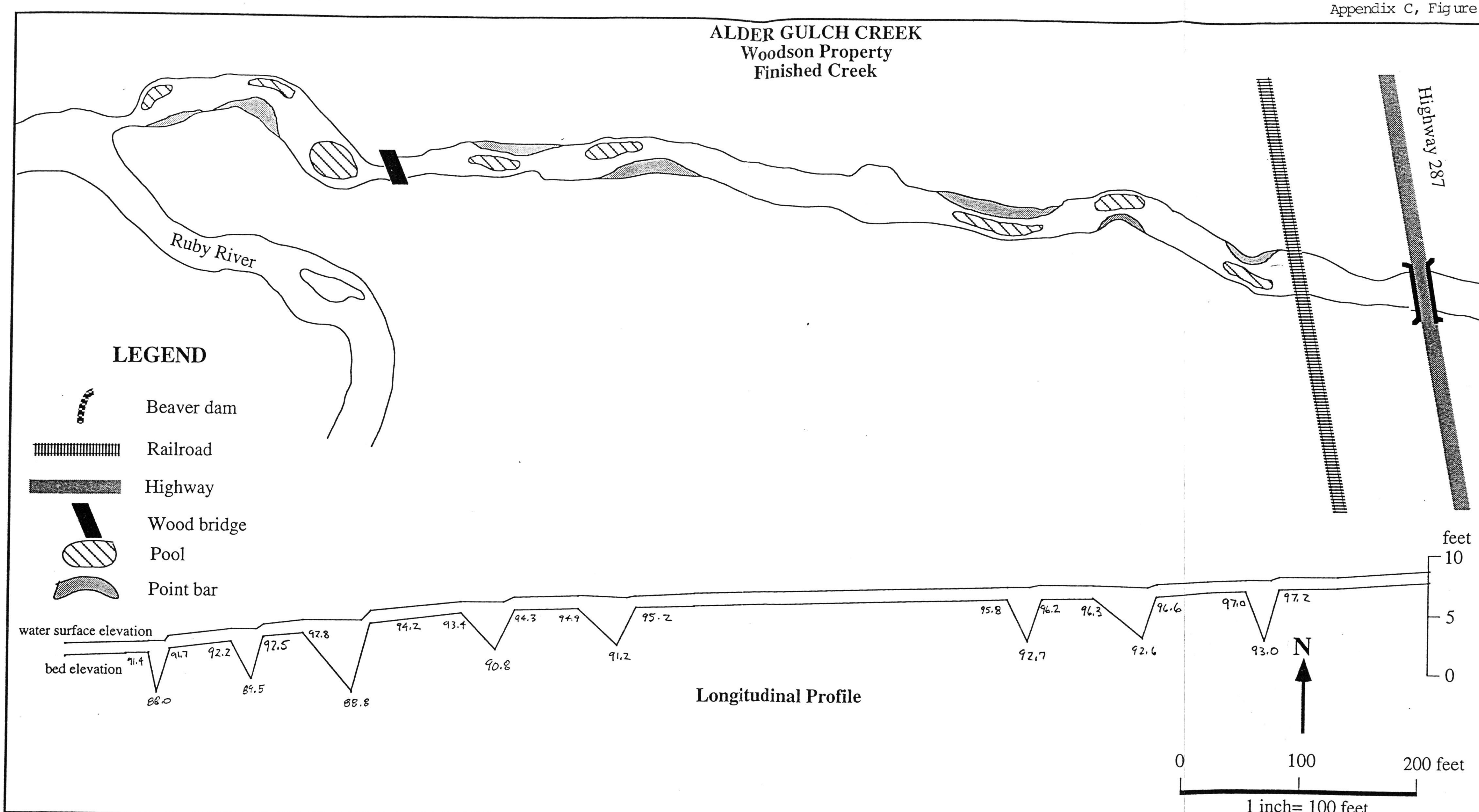
Upstream sediment trap (1995)

Appendix B, Figure 3

Cascading weirs increasing dissolved oxygen (1995)

Appendix C

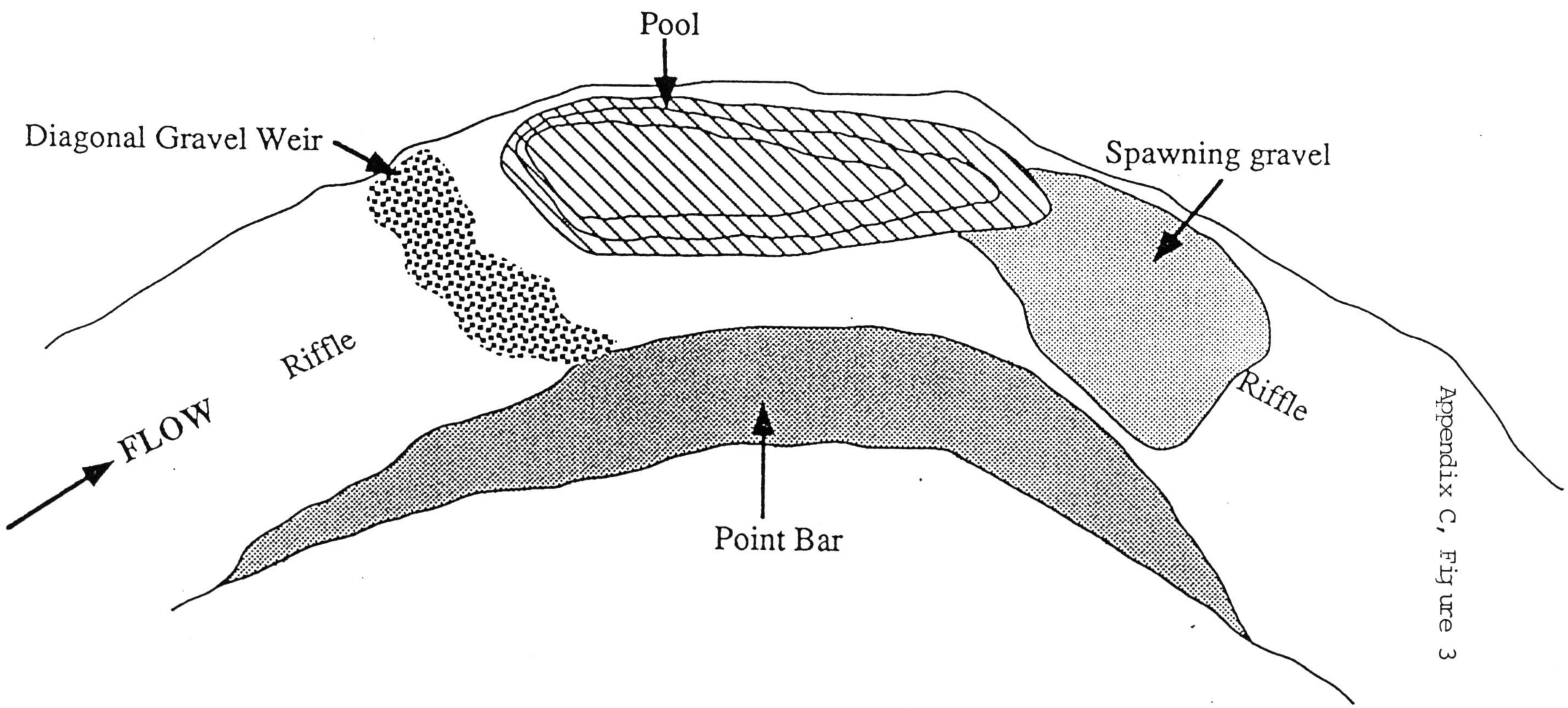

ALDER GULCH CREEK
Woodson Property
Existing Creek
Highway 287
Ruby River
LEGEND
Beaver dam
Railroad
Highway
Wood bridge
feet
10
5
0
water surface elevation
91.3
bed elevation
91.05
91.8
92.65
89.3
94.2
94.7
93.3
95.6
98.0
95.2
95.7
96.9
97.3
Longitudinal Profile
N
0
100
200 feet
1 inch= 100 feet
JOSEPH URBANI & ASSOCIATES, INC.
Fisheries Enhancement


ALDER GULCH CREEK
Woodson Property
Finished Creek
Highway 287
Ruby River
LEGEND
Beaver dam
Railroad
Highway
Wood bridge
Pool
Point bar
feet
10
5
0
water surface elevation
bed elevation
Longitudinal Profile
N
0
100
200 feet
1 inch= 100 feet

JOSEPH URBANI & ASSOCIATES, INC.

Fisheries Enhancement

TYPICAL ENHANCEMENT SITE
Alder Gulch Creek



Appendix C, Figure 3

Appendix D

Sediment filled channel prior to restoration (1993)

Restored channel and habitat enhancements (1995)

Livestock impact prior to restoration (1993)

Restored to spawning site (1995)

Excavation and boulder placement (1993)

Restored section two years later (1995)

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